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RESULTS OF A SMALL SCALE TEST TO DETERMINE DETONABILITY OF PROPELLANTS

PART II SMALL GRAIN GUN PROPELLANTS [U]

R.H. WELDON

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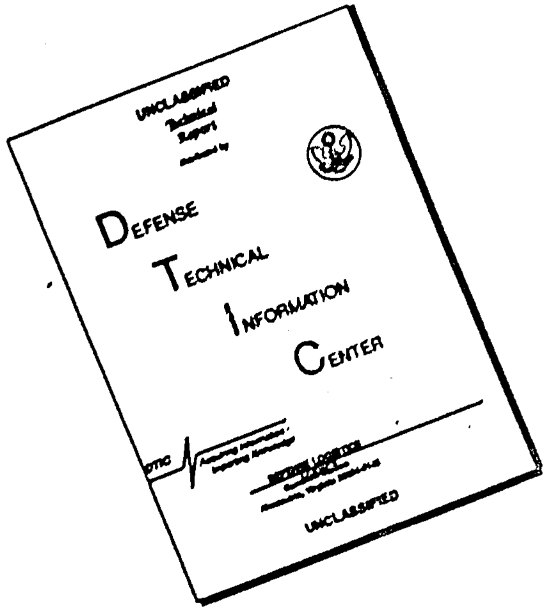

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S U M M A R Y

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1. INTRODUCTION

The response of approximately 1 kg cubic charges of rocket propellant to the shock stimulus resulting from the detonation of 35 g tetryl was previously measured(ref.1). Tests were conducted both with the charges confined in a 9.53 mm thick mild steel section of square pipe and in the unconfined condition.

It was found that composite propellants based on other than ultra-fine ammonium perchlorate (UFAP) and double base colloidal propellants with a liquid nitroester content less than 30% represented a fire risk (Category Y). Double base colloidal propellants with a liquid nitroester content equal to or more than 30% were categorised as an explosion risk (Category ZZ) as were double base propellants modified by the addition of ammonium perchlorate and aluminium or nitramine. The summarised results can be seen in Appendix I for reference and comparative purposes.

The results, when viewed in conjunction with those of a small scale velocity of detonation test, confirmed the postulate that the difference between the ignition stimulus and shock stimulus was only one of degree and suggested that gradation of response might be used for categorisation of rocket propellants.

In view of the lack of information on detonability of block charges of propellants, it was decided to evaluate the test using granular propellants, a regime in which much work has been done. If the test results were consistent with those given by critical height tests and those involving bulk burning trials, then the test would be validated and be an acceptable tool for interim categorisation purposes.

This report discusses the results of tests carried out using four single base rifle powders (AR2201, AR2203, AR3002 and AR4001) and a granular double base gun propellant, M9.

2. TESTS UNDER CONFINEMENT

To achieve conditions similar to those in the previous work(ref.1), the standard square-ended pipe was sealed at its base using a thin cardboard disc and propellant was poured into the container so formed and hand-tamped to achieve maximum mass. The units were then sealed at the top using a thin cardboard disc.

Due to the granular nature of the propellants and, in the case of AR4001, porosity, the masses under test were much less than the block charges previously tested. The mass for all the propellants except AR4001 (a very porous powder) was approximately 0.5 kg; in the case of AR4001 a fill of only 0.3 kg was achieved.

The charges were placed on two 25 mm thick mild steel witness plates and fired using the standard 35 g tetryl pellet and a No. 8 electric detonator. Figure 1 shows a charge prepared for firing. The results of all confined firings can be seen in Table 1 and the damage to witness plates in Figures 2, 3 and 4. On these figures C refers to confined condition, 1 and 2 to top and bottom witness plate respectively.

The depth of the dent in all witness plates was measured and the underside of the top witness plate examined. The reactivity, in decreasing order, of the propellants tested as gauged by dent depth was; M9 (17 mm), AR3002 (12 mm), AR4001 (9.5 mm), AR2201 (9 mm) and AR2203 (6 mm). With the exception of AR4001, this order of reactivity is consistent with critical height measurements (see Table 1). The anomaly is probably related to the low mass under test. It should be noted also that the dent depth is difficult to measure due to plate distortion and may not only indicate detonative forces but be a measure also of

the propulsive forces of these fast burning materials. Inspection of the underside of the top witness plate showed random cracking of the metal in the case of propellants M9, AR3002 and AR4001, indicating a shock stimulus to the plate rather than a propulsive force.

3. TESTS IN THE UNCONFINED CONDITION

To simulate the unconfined conditions as used in the block charges, the propellants were hand-tamped into a cardboard cartridge of the same size as the block charges previously used. Again there was a similar discrepancy between the mass of granular propellant under test and that of the block charges as referred to in paragraph 2.

The cardboard cartridge filled with propellant was placed on a 25 mm thick mild steel witness plate and fired using the standard initiation system. Figure 5 shows a charge ready for firing and Table 1, the results of each test. Figures 2, 3 and 4 show the dent produced on each of the witness plates involved, U refers to the unconfined test. The order of reactivity based on dent depth was found to be AR3002 (9.5 mm), M9 (8 mm), AR4001 (3 mm), AR2201 (2 mm) and AR2203 (0.5 mm). It is doubted whether detonation was achieved in the case of powders AR4001, AR2201 or AR2203. The reactivities were not strictly in accord with critical height assessments (see Table 1) and in the case of AR4001 probably due to the low mass involved. However, clearly AR3002 and M9 were more reactive than AR2201 and AR2203.

4. VELOCITY OF DETONATION TEST

The propellants were filled into a 19 mm diameter x 279 mm long paper tube and tamped to achieve as large a mass as possible. The filled tubes were placed on a fibreglass strip incorporating pairs of electro-deposited copper conductors and fired using 5 g Metabel and a No. 8 electric detonator. Measurement of velocity of detonation was attempted by the method discussed in reference 2. Figure 6 shows a charge ready for firing.

In the event, powders AR2201 and AR2203 extinguished at 85 mm along the charge, AR3002 at 115 mm, AR 4001 at 214 mm and M9 burnt to detonation yielding a velocity of 2700 ms^{-1}. The order of reactivity is obvious from the results, but the low packing density of the AR4001 sample probably resulted in a low assessment of its reactivity. The results are summarised in Table 1.

5. DISCUSSION OF RESULTS

All the results of the trials are summarised as follows:

TABLE 1. SUMMARY OF RESULTS

Type	Critical Height (mm)	Detonability Test				Velocity of Detonation Test (Cylindrical Sample 19 mm x 279 mm long)	
		Confined		Unconfined			
		Mass (g)	Dent Depth (mm)	Mass (g)	Dent Depth (mm)	Mass (g)	Response
Single Base (Web 0.48 mm)	380	592	(1) 6 (2) 3	593	0.5	83	Extinguished 85 mm
Single Base (Web 0.25 mm)	330	523	(1) 9 (2) 7.5	573	2	77	Extinguished 85 mm
Single Base (Web 0.16 mm)	203	452	(1) 12* (2) 6.5	494	9.5	67	Extinguished 115 mm
Single Base (Very porous)	152	273	(1) 9.5*	306	3	38	Extinguished 214 mm
Double Base (Web 0.29 mm)	178	472	(1) 17* (2) 8	515	8	70	Burnt to Detonation Velocity 2700 ms^{-1}

* Rear of top witness plate cracked

(1) Dent on top witness plate

(2) Dent on second witness plate

Results in Table 1 indicate that single base propellants in the form of single perforated cylinders down to web thicknesses of .25 mm, AR2203 (web 0.48 mm) and AR2201 (web 0.25 mm) are a fire risk rather than an explosion risk. This is consistent with recent work(ref.3) which found that a large stack of AR2201 propellant in filled boxes (55 kg per box) with a total mass of 3960 kg would not burn to detonation when initiated by a gunpowder charge and electric fuzehead. It is also consistent with their large critical heights and with the work of Hyyppa(ref.4) who found that a solid grained SB powder, contained in a brass tube of approximately 40 mm diameter and ignited by a naked flame, extinguished part of the way down the tube.

The velocity of detonation test and detonability test under confinement suggested that the porous single base propellant (AR4001) and 0.18 mm discs of AR3002 were more of an explosion risk than a fire risk. The same could be said of the one solid cylindrically-grained double base powder tested, M9 (40% NG/58% NC). These results are consistent with their critical height values which are lower than those of AR2201 and AR2203. They also agree with the work of Hyyppa(ref.4) who found that a double base powder (36% NG/63% NC) and two single base porous powders (97% NC), when filled into 39-42 mm brass tubes and initiated by a naked flame, burnt to detonation exhibiting velocities of 3880 ms^{-1}, 3780 ms^{-1} and 3350 ms^{-1} respectively. The high performance of the AR3002 propellant in disc form is related to its small web thickness 0.18 mm and its comparatively high specific surface. Calculations for a single grain show it had a specific surface of 165 cm^{-1} whereas AR2201 had a specific surface of 87 cm^{-1} and a solid cylinder of AR2201 dimensions, 70 cm^{-1}.

It is possible that multi-perforated grain SB powders could also be more of an explosion risk than a fire risk. However, no such powders were available for testing.

6. CONCLUSIONS

Tests conducted in the better established regime of small grain propellants, confirmed that the difference between shock stimulus and the normal ignition stimulus was one of degree and that a categorisation test could be based on the response of propellants to a standard shock stimulus under standard test conditions.

The test gave results that were consistent with the other relevant work and was validated as a useful small scale test for interim categorisation work.

Single base powders in the form of single perforated cylindrical grains of web thicknesses equal to or more than 0.25 mm are more of a fire risk than an explosion risk and represent an ESTC Category Y risk for storage and transportation in their standard packs.

Porous single base powders and double base powders are more of an explosion risk and represent an ESTC Category ZZ risk. Though not tested, it is possible that multi-perforated SB powders are also Category ZZ risks.

The only solid cylindrical-grained propellant tested was AR3002 which was of short length and thus had small effective web thickness and high specific surface, hence was more of an explosion risk than a fire risk (an ESTC Category ZZ risk). It is probably that, judged from specific surface calculations, solid cylindrical grains having effective web thicknesses equal to that of AR2201 and larger would be a Category Y risk.

The work confirms the findings of the previous work that the presence of 30% or more of liquid nitroester in double base colloidal propellants renders them detonable.

7. ACKNOWLEDGEMENTS

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APPENDIX I

SUMMARY OF TESTS ON BLOCK CHARGES

I.1 COMPOSITE PROPELLANTS

Binder	Burning Rate	AP/Al	Calorific Value	Detonability Test	
	($mm\ s^{-1}$)	(%)	($cal\ g^{-1}$)	Unconfined	Confined
Polyurethane	6.2	59/20	-	No Reaction	No Reaction
Polyurethane (2% DEGDN)	13.2	64/15	-	Moderate Burn	Violent Explosion
Polyurethane (6% DEGDN)	17.8	74/5	-	Rapid Burn	High Order Explosion
Polyvinylchloride	8.0	68/0	839	No Detonation	No Detonation
Polyvinylchloride	12.2	72/0	928	No Detonation	No Detonation
Polyisobutylene	-	-	-	No Reaction	No Reaction
Polybutadiene	15.3	80/3	1139	No Detonation	No Detonation

I.2 DOUBLE BASE PROPELLANTS

Type	Burning Rate	Liquid Nitroester	Calorific Value	Detonability Test		Vel. of Detonation ($m\ s^{-1}$)		
	($mm\ s^{-1}$)	(%)	($cal\ g^{-1}$)	Conf.	Unconf.	40x40	20x20	10x10
Extruded	8.9	34	849	D	D	-	6798	ND
Cast (Sustainer)	7.7	29	903	D*	ND	-	ND	ND
Cast (Boost)	13.6	42	1130	D	D	7273	7203	ND
Cast (Boost)	16.3	34	1023	D	D	7430	7163	ND

D Detonation

ND No Detonation

* Small Dent Only

I.3 MODIFIED DOUBLE BASE PROPELLANTS

Type	Burning Rate	Liquid Nitroester	RDX	AP/Al	Calorific Value	Detonability Test		Vel. of Detonation ($m\ s^{-1}$)		
	($mm\ s^{-1}$)	(%)	(%)	(%)	($cal\ g^{-1}$)	Conf.	Unconf.	40x40	20x20	10x10
AP/Al	19.3	30	-	24/17	1675	D	D	7294	6694	ND
Nitramine	7.6	29.5*	30	0/7	1055	D	-	-	-	7140
Nitramine	6.2	29.5*	30	0/4	1090	D	-	-	-	7271
Nitramine	7.1	29.5	30	0/7	1117	D	-	-	-	7406
Nitramine	6.6	29.5	30	0/4	1146	D	-	-	-	7453

D Detonation

* 7% DEGDN, 22.5% NG

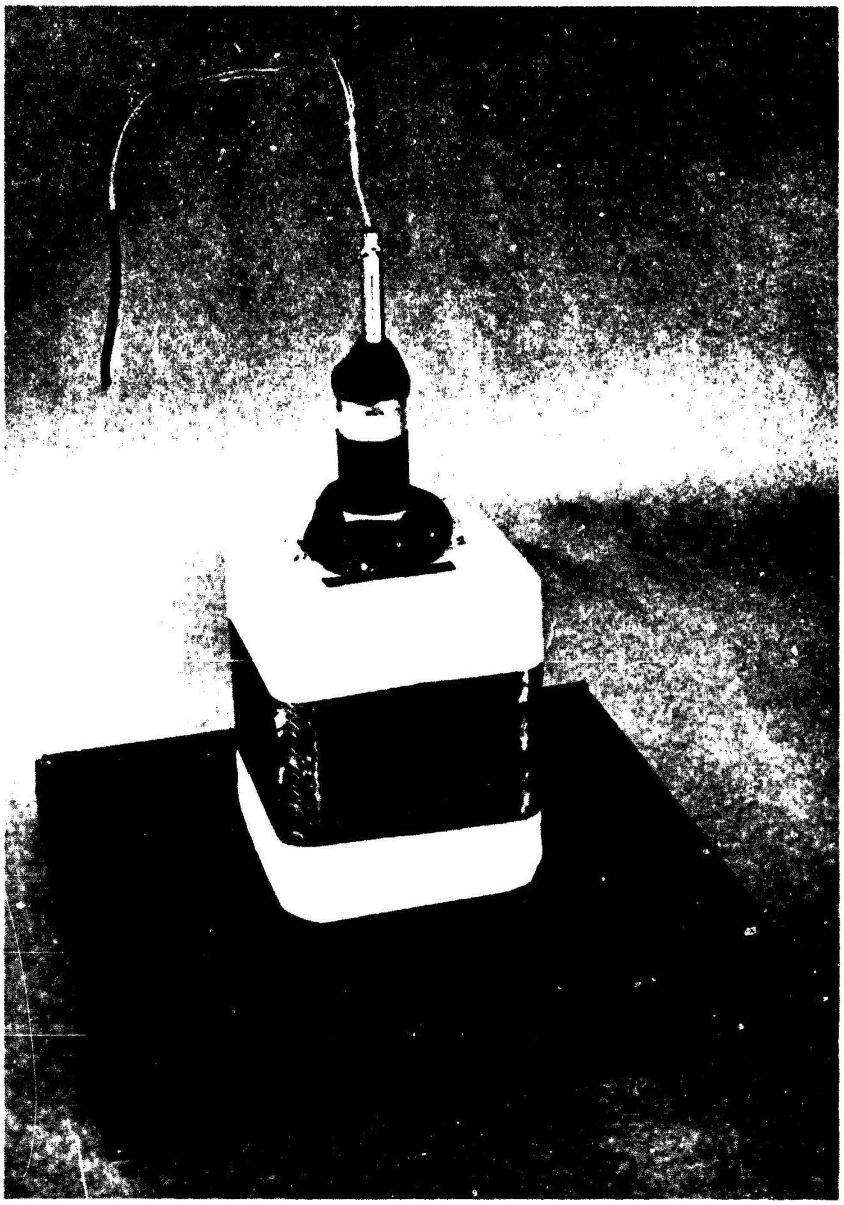

Figure 1. Charge ready for firing (confined condition)

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Figure 2. Damage to witness plates, propellants AR2201 and AR2203

Figure 3. Damage to witness plates, propellants M9 and AR3002

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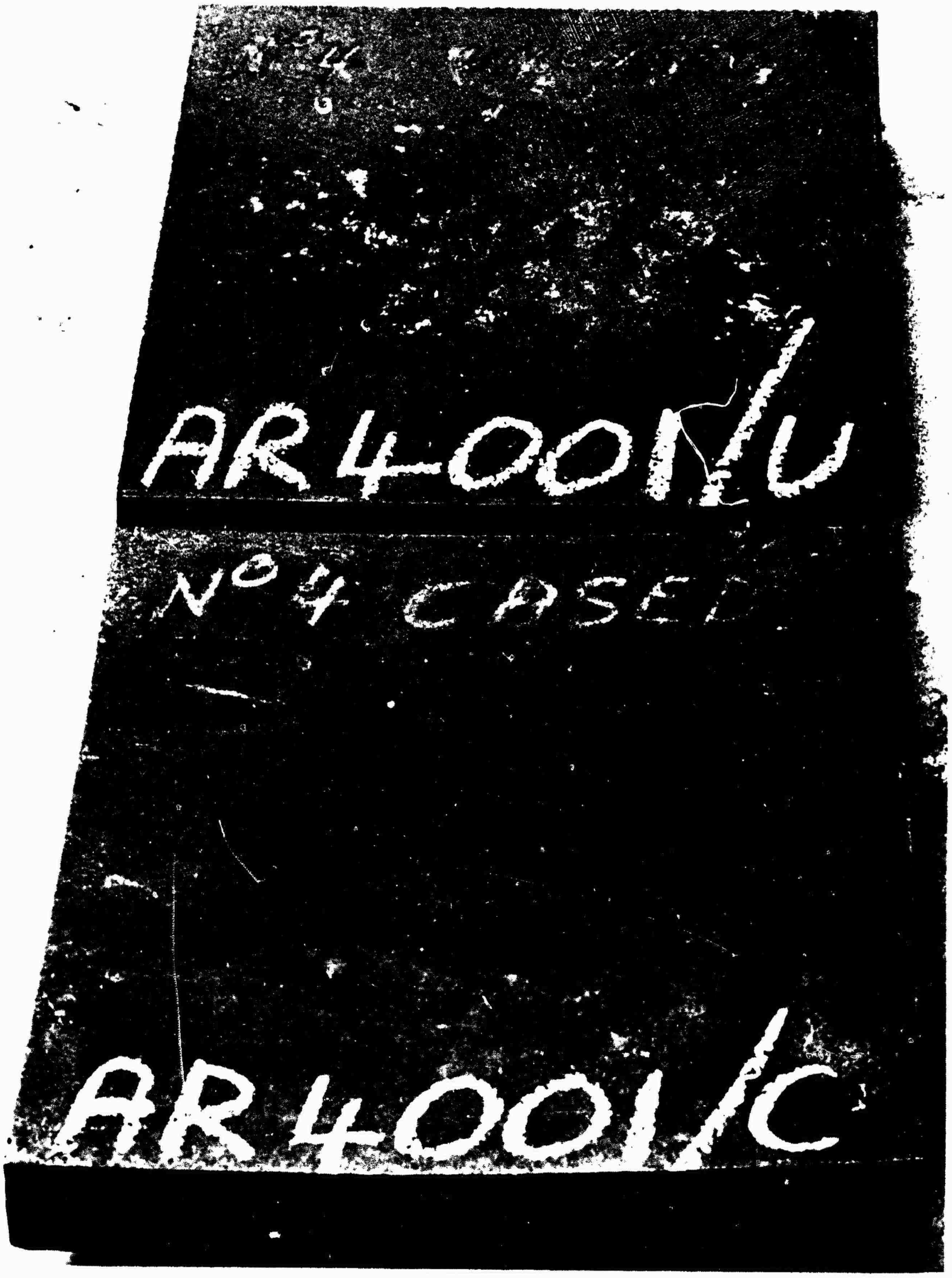

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Figure 5. Charge ready for firing (unconfined condition)

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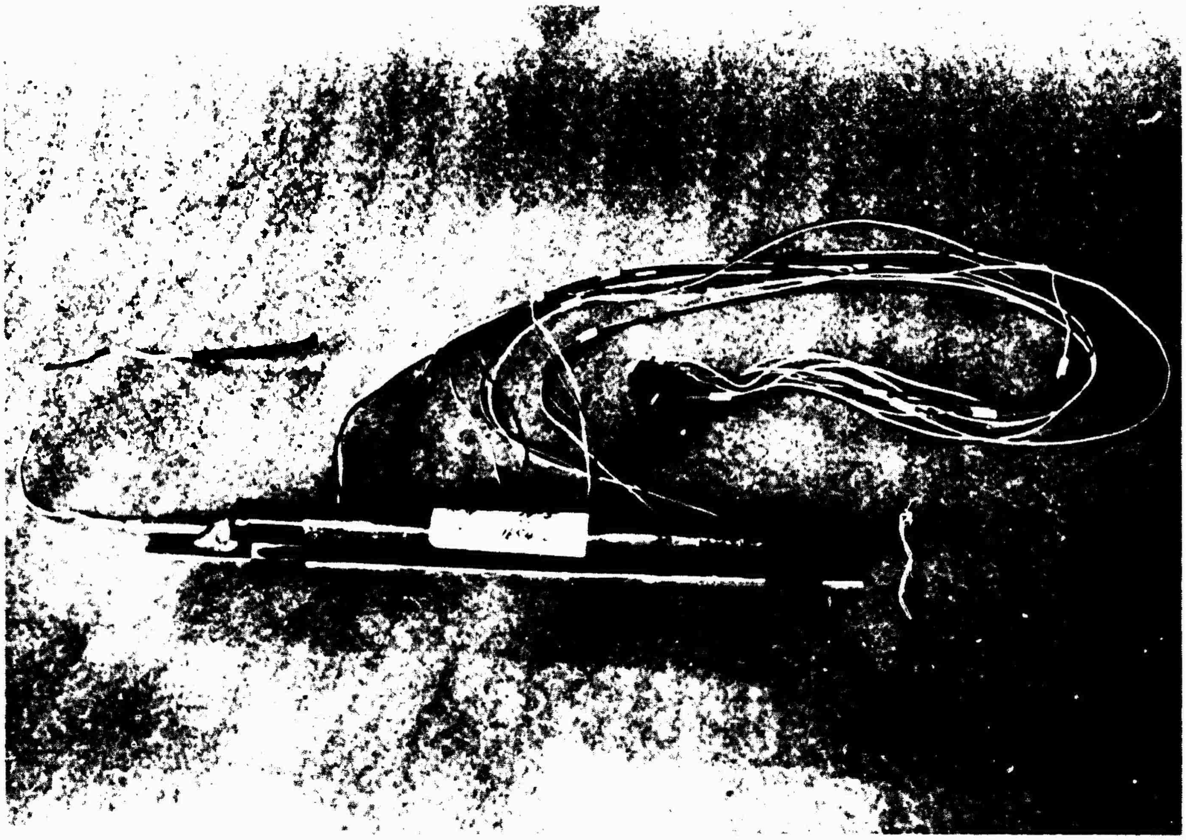

Figure 6. Cartridge assembled for velocity of detonation test

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